Table 1.--Characteristics of slate quarries and dumps in the Stroudsburg quadrangle

Quarry no.	Name	Approximate length and width (in feet)	Maximum depth (in ft)	Height of adjoining dumps (in ft)	Remarks	Structural data				References /(1) Behre, 1933; (2) Epstein, 1971; (3) Sanders, 1883/
						Bedding	Cleavage	Joints	Faults	
1	Bangor Fidelity (on southwest) and West Bangor (on northeast)	550 X 225 (Bangor Fidelity) 450 X 350 (West Bangor)	300*	120	Flooded. Maximum of 40 ft of rock exposed above water. Two quarries separated by a wall of slate about 100 ft wide (fig. 4A). About 10 ft of glacial till caps the slate.	Beds dip moderately northwest at the northwest end of the openings and are overturned steeply to southeast in the southeast end. Quarries are in an overturned syncline (fig. 4A).	Strike averages N.50°E., dip 15°-39°SE.	N.55°E., 75°SE.-vert.; N.10°-30°E., 70°SW.	Bedding slip fault and shatter zone midway up quarry.	(1) p. 237, 246-247. (2) p. 163-164.
2	Bangor Superior	L-shaped opening; 270 X 230 & 140 X 70	180*	75	Flooded. Birch Reservoir of Bangor Water Company. About 15 ft of rock exposed above water in northwest wall. 5-10 ft of glacial till caps the slate.	N.60°W., 12°SW.	N.62°E., 39°SE.	N.32°E., 27°NW.; N.43°W., 69°NE.; N.52°E., 78°SE.; E-W, 18°N.; N.13°E., 44°SE; N.75°W., 62°SW.; N.30°E., vert.; N.8°E., 53°SE.; N.4°W., 78°NE.		(1) p. 347-348. (2) p. 163-164.
3	Northampton	280 X 260	230+	70	Former garbage dump for Borough of Roseto; dumping ceased about 1968. Quarry filled with garbage (fig. 4B).	N.55°E., 85°SE. (overturned) in north wall and N. 50°E., 53°NW. in south wall. Quarry is in overturned syncline (fig. 4B).	N.80°E., 22°SE. in north wall and N.25°E., 10°SE. in south wall.	N.40°W., vert.; N.60°E., 45°-50° NW. (most prominent); N.60°W., 45°SW.	Two 1-inch-wide fractured calcareous beds 200 ft below top in middle of northeast wall. Bedding slip fault with distorted cleavage and many joints in northeast wall.	(1) p. 218, 221-222. (2) p. 165-166.
4	Hoboken quarry	150 X 80	50*	30	Flooded. Maximum of 8 ft of slate exposed above water. About 6 ft of glacial till overlies slate.	N.22°E., 10°NW. in north wall and N.32°E., 20°NW. in south wall.	N.60°E., 37°SE.	N.10°W., 70°NE.; N.73°W., 65°SW.; N.58°E., vert.		(1) p. 204. (2) p. 165.
5	New York	275 X 225	210 (at south end)	85	Flooded. Pumped for public water supply. Oxford Reservoir of Bangor Water Company. About 20 ft of glacial till overlies slate in north end of quarry.	Beds dip 22°-30°NW. and strike nearly due north (Behre, 1933, p. 203).	N.60°-70°E., 23°SE.	N.48°W.; N.20°-35°E., 60°NW.-vert.; N.36°E., 45°SE.	Two bedding-plane slips, 4 ft apart, near middle of quarry wall. Zones are filled with calcite and some quartz. Cleavage has been dragged along slip surfaces.	(1) p. 202-204. (2) p. 165, 167.
6	New Peerless (Bangor Vein)	660 X 290	205*	60	Flooded. Pumped for public water supply. Smith Reservoir of Bangor Water Company. Some machinery remains. 35 ft of slate exposed above water. Glacial till a few feet thick or absent.	Beds generally strike N.56°-84°E. and dip 1°-37° SW. (overturned), but in one place are doubly overturned to northwest (figs. 4C and D). At depth (60 ft below surface in northeast wall and and 100 ft below surface in southwest wall) beds are right side up and dip a maximum of 60°N. (Behre, 1933, p. 205). Quarry is in a nearly flat-lying syncline (fig. 4D).	At surface parallel to nearly parallel to bedding. Some cleavage has been folded.	N.30°W., 45°NE.; N.55°W., vert.	Bedding slip fault at depth (fig. 4D) along which cleavage is warped and rock is shattered and filled with quartz. Above fault is series of small joints (N.60°E., vert.).	(1) p. 204-205. (2) p. 167-171.
7	Strunk	190 X 160	80*	60	Flooded. 20-30 ft of slate exposed above water. Some trash in water.	Beds in north wall N.47°E., 15°NW. and N.68°E., 47°NW. near south wall (fig. 4C). Beds overturned to southeast near water level (Epstein, 1971, fig. 65). Quarry is in same faulted syncline as New Peerless quarry.	At surface, N.33°-79°W., 18°-26°SW.	One prominent joint: N.48°E., dips steeply south.	Same bedding slip fault as in New Peerless quarry (fig. 4D).	(1) p. 204. (2) p. 167-171.
8	Capozzolo	300 X 200	45	None in 1972.	Opened in 1971.	N.75°E., 16°SE., overturned.	N.52°W., 15°SW.	N.24°W., 55°SW.; N.60°E., 37°NW.; N.5°W., 71°NE.; N.84°E., 87°NW.; N.75°E., 35°SE.; N.62°E., 75°NW.; N.13°W., 70°NE.		
9	Mountain View	105 X 95	60	30	Flooded. Many fish. About 20 ft of slate exposed above water.	N.10°W., 10°SW.	N.75°E., 17°SE.	N.32°W., vert.; N.45°W., 55°NE. (prominent); N.20°-60°E., vert.		(1) p. 207. (2) p. 173.
10		140 X 90	5	Nearest dumps are 200 ft SE. close to quarry 11.	Glacial till, about 4 ft thick, overlies slate.	N.38°E., 12°-17°NW.	N.88°W., 10°-20°SW.	N.21°W., 83°NE.; N.64°W., 64°SW.; N.29°E., 58°NW.; N.16°E., 44°SE.		(1) p. 173.
11		50 X 25	Shallow		Commercial quality slate was probably not obtained here because of several thin sandstone beds in quarry.	N.70°E., 8°NW.	N.63°E., 15°SE.			(2) p. 173.
12		50 X 25	20?		Commercial quality slate was probably not obtained because of sandstone bed. 8 ft of slate exposed above water.	N.35°E., 24°NW.	N.55°E., 2°SE. in slate; N.63°E., 30°SE. in 10-inch-thick sandstone bed.	N.10°E., vert.		(1) p. 207. (2) p. 173-174.
13	Shimer	230 X 210	130*	60	Flooded. About 15 ft of rock exposed above water in north part of quarry. Fig. 4E. Slate overlain by about 5 ft of glacial till.	N.35°-50°E., 3°-9°NW. at surface.	N.45°-70°E., 10°-17°SE.			(1) p. 208. (2) p. 174-175.
14	Consolidated No. 3	650 X 200, irregular in shape	100+	100-120	Flooded. 20-100 ft of slate exposed above water. Southern section is former garbage dump for town of East Bangor; dumping ceased in 1971 (fig. 4E). Slate overlain by 3 ft of glacial till on northern wall and 8 ft on western wall. Many thin siltstone beds.	N.5°E., 5°NW. at northeast end to N.31°W., 9°SW. at south end.	N.79°W.-N.85°E., 17°-28° SE. to SW.	N.32°E., 84°SE.-vert. (prominent); N.42°W., 77° NE. (prominent); N.44°W., 73°SW. (prominent); N.50°E., 66°NW. (prominent); N.45°E., 83°NW.; N.8°E., 51°-70°NW.; N.48°W., 65°NE.; N.40°E., 50°SE.; N.22°W., 80°NE.-vert.; N.15°E., vert.; N.50°E., vert.; N.65°E., vert.; N.60°W., 70°SW.; N.50°W., vert.; E., 35°S.	Some slippage along bedding indicated by slickensides (scratches).	(1) p. 207-208. (2) p. 174-175.
15	Consolidated No. 2	425 X 400	100*	120	Flooded. Maximum of 35 ft of rock exposed above water in northwest wall (fig. 4E). Almost 5 ft of glacial till overlies slate.	N.57°W., 3°-10°SW.	N.82°-87°E., 22°-31°SE.	N.45°W., 62°NE. (prominent); N.20°E., 80°SE.; N.28°W., 65°NE.; N.40°E., vert.; N.22°W., 80°NE.; N.5°E., 87°SE.		(1) p. 208. (2) p. 175-176.
16	Capitol Slate (formerly Consolidated No. 1-Star)	900 X 700	275	100	Flooded. Closed about 1970 because of labor problems. Southwest section (230 X 600 ft) was most recently worked (fig. 4F). More than 25 ft of glacial till overlies slate in northeast corner.	Generally dipping moderately to northwest in southeast wall, and dipping gently to southwest in remainder of quarry as trough of syncline is approached.	N.83°W.-N.69°E., 17°-30°SE. One reading in west corner, N.48°E., 21°SE.	See figure 8.	Five-inch-thick shear zone (bedding slip fault) containing quartz, calcite, and slate fragments in north corner of quarry.	(1) p. 208-210. (2) p. 176-179.
17	Standard	275 X 240	115*		Flooded. About 30 ft of rock exposed above water in north wall. About 10 ft of glacial till overlies slate in northeast corner.	N.20°E., 14°NW.	N.82°E., 23°SE.			(1) p. 210-211. (2) p. 179.
18	Bangor Valley (formerly Bangor Eclipse)	300 X 150	130*	80	Flooded. About 50 ft of rock exposed above water in northwest wall. About 10 ft of glacial till overlies slate in northwest wall.	N.80°E., 7°NW.	N.68°E., 23°SE.	N.79°W., 65°SW.; N.8°W., vert.; N.45°W., vert.; N.55°E., 35°SE.; N.55°E., 50°NW.		(1) p. 211. (2) p. 179.
19	Bangor Central	210 X 180	250*	70	Flooded. About 60 ft of slate above water in northwest wall. About 20 ft of glacial till at north end and 10 ft at south end.	N.35°W., 4°SW. in southwest corner. Increases to 13°NW. in northwest wall.	N.71°E., 29°SE.	N.65°W., vert.; N.50°E.; E., vert.		(1) p. 211-212. (2) p. 179.
20	Bangor Royal	250 X 180	100	180	Flooded. Formerly garbage dump for town of Bangor; dumping ceased in 1971 due to possible pollution of nearby stream. Incinerator located on dumps to west. About 40 ft of slate exposed above water in northwest wall.	N.40°E., 18°NW. (approximate).	N.75°E., 16°SE. (approximate).			(1) p. 212. (2) p. 179.
21	Bangor Excelsior	550 X 425	140*	200	Flooded. About 70 ft of slated exposed above water in southeast wall (fig. 4G).	N.29°E., 22°NW. in east wall; N.21°E., 9°NW. in north corner. Overturned anticline and syncline at depth (see fig. 4G).	N.32°-48°E., 10°-21°SE.	N.45°W., vert.; N.2°E., vert.; N.70°E., 52°SE.; N.76°E., 42°NW.; N.77°W., 76°SW.; N.30°-40°E., vert.; N.80°E.-N.80°W., vert.; N.60°-65°W., vert.		(1) p. 214. (2) p. 180-182.
22	New Bangor (on southwest) and Columbia Bangor (formerly Ditchett's) (on northeast)	1200 X 250 (combined)	110*		Flooded. About 60 ft of slate exposed above water in southeast corner and 10 ft in northwest wall. Slate is covered by about 15 ft of glacial till in north corner of quarry. Fly ash was dumped in New Bangor quarry in 1972.	N.21°-28°E., 8°-14°NW. in south part (on upright limb of overturned recumbent anticline) and overturned 20°-28°SE. in north part (on overturned limb of anticline). See figure 4G.	N.32°-49°E., 15°-25°SE. in upright limb; N.11°-38°W., 10°-20°SW. in overturned limb.	N.32°-35°E., 72°-86°NW.; N.74°-79°W., vert.; N.38°-45°E., 26°-32°NW.; N.3°E., 26°-83°NW. (curved); N.40°-65°E., 40°-75°NW.; N.36°-41° W., 81°-86°NE.; N.64°E., vert.; N.25°E., 83°SE.		(1) p. 212-214. (2) p. 180-182.
23	Emory Pipher (formerly Enterprise)	150 X 70	10	20	Flooded. Located in creek. Small exposures of slate and some thin sandstone beds on NW. side. Slate is overlain by a few feet of glacial till.	N.28°E., 14°NW. on northwest side of small fold; N.37°E., 9°SE. on southeast side of small fold.	N.17°E., 9°NW. on northwest side of small fold; N.57°E., 22°SE. on southeast side of small fold.	N.27°E., 41°SE.; N.74°W., 81°NE.; N.42°E., vert.		(3) p. 88. (2) p. 182.
24		Circular, 40 ft across	10		In creek. Dammed for local water supply. Thin sandstones interbedded with slate.	N.44°-55°E., 19°-22°NW.	N.84°E., 11°SE.	N.55°E., 72°SE.; N.38°W., 52°SW.; N.77°E., 84°NW.		(2) p. 182-183.
25	Washington Brown (formerly John Morrison's?)	100 X 60	42 in NW. part	20	Flooded; overgrown. 18 ft of rock exposed above water in northwest corner. Referred to as Washington Brown quarry by Behre (1933, p. 198) and John Morrison's quarry by Sanders (1883, p. 86).	N.31°E., 20°NW.	N.12°W., 14°SW.	N.37°W., 80°SW.; N.60°E., vert.		(3) p. 86. (1) p. 198.

*Indicates that depths below water level were sounded with weighted wire and variations in depth are shown in figure 1.

SLATE--A MINERAL RESOURCE

The first slate quarry in Pennsylvania began operation in 1812 near Bangon (Merriman, 1898), and since then more than 400 quarries have been opened in the slate belt of Northampton and Lehigh Counties in eastern Pennsylvania. At present, less than a dozen of these are active. Even so, Pennsylvania still leads in the production of slate in the United States. According to the U.S. Bureau of Mines (unpub. data), 44,250 short tons of slate (dimension stone) with a value of $3,705,329 were produced in Northampton County, and 1,547 short tons were produced in Lehigh County in 1970.

Of the 25 openings in the Stroudsburg quadrangle, only one is presently active. Some of the impacts of the slate quarries and dumps on the environment are discussed below. The locations of the quarries and dumps are shown on the map; table 1 gives the dimensions of quarries and associated dumps and their geologic characteristics, and figure 1 shows the depths of many of the quarries. Sanders (1883), Dale and others (1914), and Behre (1933) have also described some of these quarries.

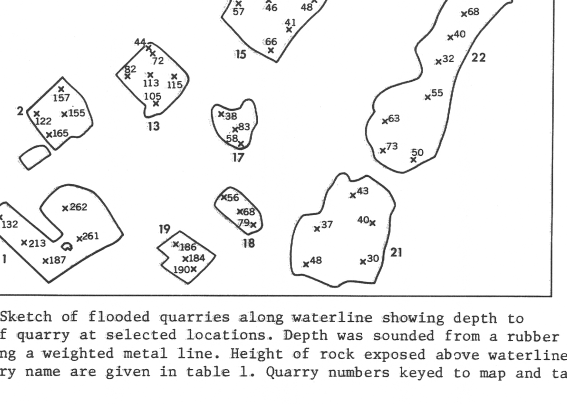

FIGURE 1. Sketch of flooded quarries along waterline showing depth to bottom of quarry at selected locations. Depth was sounded from a rubber raft using a weighted metal line. Height of rock exposed above waterline and quarry name are given in table 1. Quarry numbers keyed to map and table.

Geology

The slate in the Stroudsburg quadrangle is in the Martinsburg Formation of Ordovician age, about 450 million years old. A geologic description of the formation is given by Epstein (1971, 1973). The northern outcrop limit of the Martinsburg is at the base of Blue and Kittatinny Mountains, which are underlain by resistant sandstones of the Shawangunk Formation of Ordovician(?) and Silurian age (about 425 million years old). The Martinsburg Formation is exposed in roadcuts, on the highest hills, in creeks, and in the slate quarries. Elsewhere a cover of glacial deposits may be more than 175 feet thick and accounts for the absence of slate quarries in those areas.

Slate is a fine-grained rock that can be split into thin smooth slabs. The planes along which the splitting takes place are the cleavage (or "split" of the quarrymen). Beds or bedding in the slate are layers of different shades of gray or layers of different composition--some beds may be nearly black because they contain a relatively high percentage of carbonaceous matter; others may be gritty because of abundant sand. The bedding is the result of different kinds of mud and sand that were deposited alternately as horizontal layers in the ocean that occupied this part of eastern Pennsylvania about 450 million years ago. After deposition, the muds and sands were compacted into solid shales and sandstones, and, many millions of years later, mountain-building forces folded (bent) and faulted (broke the beds. Today, as seen in the quarries, the beds are inclined at many different angles; some are vertical, and some have been roatated more than 90° and are overturned or upside down. During the folding the minerals that made up the original layers, especially the shales, were realined in a new direction at some angle to the original bedding. This realinement defines the cleavage and allows the rock to be split along the cleavage planes. Also during the folding, stresses were set up in the rocks which resulted in the formation of fractures or joints. If there has been movement of the rock along the fractures, the fractures are termed faults. If the faults are parallel or nearly parallel to the bedding, they are called bedding-slip faults (also called "loose ribbons" by quarrymen). The geologic features described above are illustrated in figure 2.

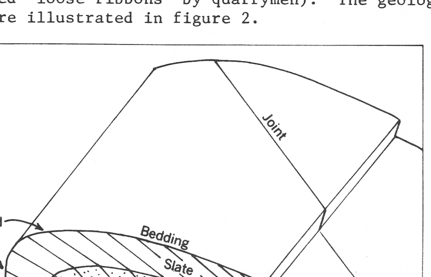

FIGURE 2. Sketch of folded slate and sandstone showing cleavage, bedding, a fault, and a joint. Note that the cleavage in the sandstone is comonly not at the same angle as in the slate.

The bedding, cleavage, joints, and faults are planar features whose attitudes are described by their strike and dip (fig. 3). Strike is a line that a planar feature would make if it intersected a horizontal surface. The dip is the angle of tilt the planar feature makes with the horizontal surface. Strike and dip symbols of beds and cleavage in some of the quarries are shown in figure 4.

Value of slate related to geologic setting

The planar features described above are very important in quarry operations and may determine whether a quarry is profitable or not. Certain groups of beds contain high-quality slate (called runs by quarrymen) and are followed down the dip as the slate is removed. These beds are generally thick, they may be homogeneous in their color and composition, and they lack such deleterious components as abundant sand-sized quartz grains, pyrite that may discolor the slate upon weathering, irregularities in the cleavage, and others. If the angle of dip of the run is gentle, the quarry will expand over a large area during slate removal (as in quarry 16). If the dip is steep, the quarry will be narrow and deep (fig. 5). The Parsons quarry, south of Pen Argyl and 1.3 miles southwest of the Stroudsburg quadrangle, is in steeply dipping beds and is reported to have been about 900 feet deep, the deepest slate quarry in the United States. In some quarries, the beds are so complexly folded that individual runs may be repeated at depth (figs. 4B, D, G).

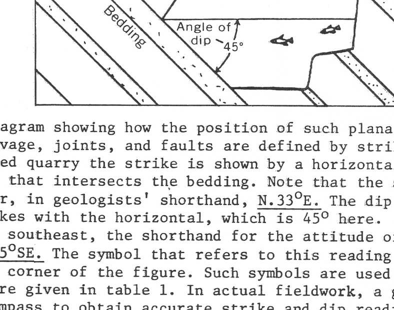

FIGURE 3. Diagram showing how the position of such planar features as bedding, cleavage, joints, and faults are defined by strike and dip. In this flooded quarry the strike is shown by a horizontal surface (the waterline) that intersects the bedding. Note that the strike is 33° east of north or, in geologists' shorthand, N.33°E. The dip is the angle that the bed makes with the horizontal, which is 45° here. Because the beds dip to the southeast, the shorthand for the attitude of these beds is N.33°E., 45°SE. The symbol that refers to this reading is shown in the upper left corner of the figure. Such symbols are used in fig. 4 and readings are given in table 1. In actual fieldwork, a geologist uses a Brunton compass to obtain accurate strike and dip readings.

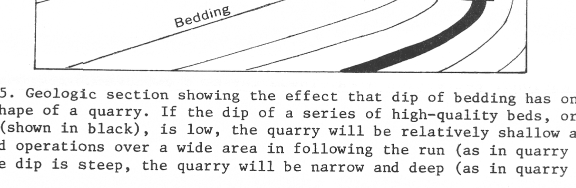

FIGURE 5. Geologic section showing the effect that dip of bedding has on the shape of a quarry. If the dip of a series of high-quality beds, or runs (shown in black), is low, the quarry will be relatively shallow and expand operations over a wide area in following the run (as in quarry A). If the dip is steep, the quarry will be narrow and deep (as in quarry B).

Cleavage is very important because it is this feature that makes a rock a slate. The cleavage must be continuous through the rock, and it must not be irregular or curved (curled). If the angle between the cleavage and a desirable bed of a given thickness is high, the piece of slate is short. If the angle is low, the piece of slate is, conversely, long (fig. 6). Thus, low angles between bedding and cleavage is a desirable feature. The dip of cleavage is also important because it generally controls the slope of the floor of the quarry and may cause it to be inconveniently steep or even dangerous. Blocks of slate that have been pried loose have slid on the cleavage-controlled floor and have injured workers nearby. In the Stroudsburg quadrangle, the dip of the cleavage is low to moderate and averages about 19°. The angles of the dip of cleavage and bedding in the slate quarries are given in table 1 and shown on figure 4. Additional readings outside the quarries are shown on the geologic map of the Stroudsburg quadrangle (Epstein, 1973).

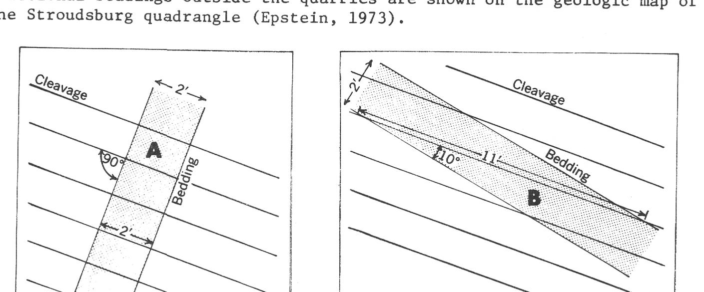

FIGURE 6. Diagram showing how the angle between bedding and cleavage determines the length of slate that may be derived from a bed of a given thickness. The beds in A and B are both 2 ft thick. In A, bedding is at a high angle (90°) to cleavage, and the length of slate (or "split" of quarrymen) is 2 ft, the same as the thickness of the bed. In B, the angle between bedding and cleavage is only 10° and the length of slate is 11 ft.

Joints are natural breaks in the rock and may be beneficial by causing the slate to break into blocks that may be conveniently handled in the quarry. On the other hand, if the joints are too close together or are at low angles to each other, large blocks of slate cannot be obtained and the rock is worthless. Joints, as well as faults and sometimes bedding and cleavage, are also natural channelways for the movement of ground water, and in a few quarries excess seepage may be a problem. The joints that were measured at each quarry are listed in table 1.

Uses for milled slate

Slate taken from the quarries has had a variety of uses, including roofing material, blackboards, aquaria bottoms, billiard table tops, electrical panels, switchboards, flagstones, floor tiles, mantles, sills and treads, grave vaults, tubs, vats, sinks, laboratory table tops, well covers, and breadboards, as well as having been crushed to flour for filler in point, linoleum, and many other products, and crushed for granules in the manufacture of composition roofing.

Uses for waste slate

Waste constitutes 50-85 percent of the rock excavated from the slate quarries, most of which is placed in large steep dumps near the quarries. The waste predominantly consists of large blocks of slate which may be more than 10 feet long. The heights of the dumps (table 1) and the areas shown on the map may be used to calculate the approximate volume of materials in the dumps. The dumps in the Stroudsburg quadrangle cover about 143 acres in total. Potential uses for this waste material are given by Dale (1914, p. 192-193) and Behre (1933, p. 105-106). In addition, an investigation of the properties of slate in order to determine new uses for the large amounts of waste was undertaken in 1932 by the Minerals Industries Experiment Station of the Pennsylvania State College (Pennsylvania State College, 1947; Stickler and others, 1951). Some of the uses, that would make the waste slate a valuable resource and eliminate the piles as an environmental annoyance, are as leightweight aggregate (O'Neill and others, 1965, p. 12-15, table 9), mineral wool for insulation, slate-lime brick, resin-bonded molded products, roofing granules, accoustical tile, road asphalt, abrasive soap, fence posts, and filler in a large variety of products including synthetic slate, roofing mastic, plastic where acid resistance is required, oilcloth, linoleum, rubber, paints, ceramic ware, etc.

The waste piles west of the Old Bangor Slate quarry, 1,000 feet south of the Stroudsburg quadrangle on the west side of Pa. Rte. 712 in the Bangor quadrangle, have been used recently by Pennsylvania Lightweight Aggregate, Inc., for production of lightweight aggregate. In 1970, 30,760 short tons of waste slate valued at $215,320 were used to make aggregate at this locality, according to the U.S. Bureau of Mines (unpub. data). The plant is not now in operation.

EXTRACTION OF SLATE AND ITS ENVIRONMENTAL EFFECTS

Hazards

Many of the flooded quarries are a potential safety hazard--drownings of swimmers and scuba divers have been reported. Outside the Stroudsburg quadrangle, fences have been erected around some quarries at great expense to the owners to keep trespassers out. Three quarries in the quadrangle and seven south and east of Delaware Water Gap are located in the Delaware Water Gap National Recreation Area. These may be a potential hazard to the millions of people that are expected to visit the area.

Many faults in the quarries are filled with the minerals quartz and calcite ("spar") and are also zones of movements of ground water (table 1). The rock along the faults may, therefore, be deeply weathered or "rotted." This creates a serious problem in quarry operation. In many cases, removal of slate will stop at a fault because of the poor quality of the rock. Additionally, the fault can be dangerous because it is a plane above which the rock may slide down into the quarry, sometimes without warning, and injure or kill workers below (fig. 7).

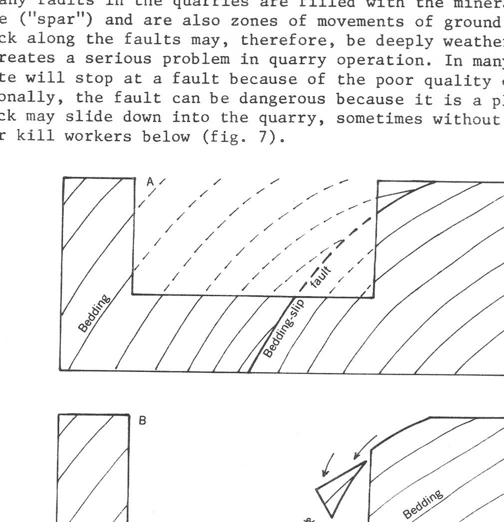

FIGURE 7. Hazardous geologic conditions involving a bedding-slip fault that could result in the sliding of a large block of rock into a slate quarry. In A, bedding below the fault parallels the fault, whereas the beds above the fault are cut by it. The fault is inclined to the quarry wall and dips into the quarry. The fault is a zone along which the rocks have moved past each other and is therefore a zone in which the rocks have been ground up and are "loose." Movement along the fault may be facilitated by the presence of water seeping through the zone. These conditions will allow the block of rock above the fault to slide down into the excavation below with danger to workmen, as in B.

Death and injury of workers caused by falling rock in actively worked quarries in the slate belt of eastern Pennsylvania are all too common. Between 1960 and 1970, a yearly average of 514 men have worked in the slate quarries of eastern Pennsylvania. Between 10 and 14 quarries were active each year. There were seven fatalities during this period and 368 nonfatal injuries (unpub. data from U.S. Bureau of Mines).

Effects of blasting in the quarries

Blasting in active quarries may be a source of concern in the location of building foundations because of possible transmission of vibrations. It is probable that there would be no seismic effects from blasting on structures more than a few hundred feet from a quarry (Thoenen and Windes, 1942, p. 80). Likewise, air-blast waves probably would cause no problems (Nicholls and others, 1971, p. 13). The charges in the quarries generally are small, just large enough to loosen a block of rock and not shatter it. However, technical advice should be obtained for building sites near active slate quarries to evaluate possible seismic effects associated with blasting.

Possible pollution of water supplies

Three of the abandoned quarries have been used in the past for public garbage dumps (quarries 3, 14, and 20) and several others have smaller amounts of trash in them. Schneider (1970) has shown that pollution of water supplies from such open dumps is possible because of percolation of leachate containing pollutants into the ground-water system (see discussion of "Use of abandoned quarries for sanitary landfills"). Also, the water in some quarries flows out into nearby streams and could pollute them.

PLANNING FOR FUTURE SLATE EXTRACTION

Slate reserves--prospecting for slate

Areas of potential commercial slate are shown on the accompanying map. These areas generally follow belts of slate quarries, probably do not have a thick overburden (thickness of overburden in some areas is shown on the map), and, judged from the geologic map (Epstein, 1973), may not have abundant deleterious sandstone mixed in with the slate. Procedures for prospecting, as well as descriptions of quarry and mill practice, are given by Sanders (1883, p. 138-143), Dale and others (1914, p. 167-171), Behre (1933, p. 11-21, 68-73, 81-102), Stickler and others (1951, p. 11-32), and Bowles (1955, p. 8-10). Exploration of a site should preferably begin by core drilling to determine the quality and thickness of slate and depth of overburden (glacial deposits, if present, and weathered slate or "top"). The overburden should be thin, generally less than 20 feet, so as to avoid costly stripping operations and extensive cribbing. Structural features must be determined, such as the character of the jointing, presence of faults or curved cleavage, etc. The locations of the dumps have to be determined so as to avoid placing them over rock that may be worked in the future. Drainage has to be considered because excessive water results in costly pumping, but moderate amounts of water are needed to keep the slate from becoming brittle. Finally, the slate has to be tested, including its sonorousness, cleavability, cross fracture ("sculp" or "grain"), color and discoloration, presence of undesirable minerals, character of cleavage surface, electrical resistance, strength, toughness, elasticity, density, porosity, hardness or abrasion, corrodibility, microscopic analysis, and chemical analysis (Merriman, 1898, p. 85-89; Dale and others, 1914, p. 171-189; Behre, 1933, p. 73-81).

Multiple land-use planning

The increasing concern for mined-out areas not being considered for alternate land uses is expressed in the Surface Mining Conservation and Reclamation Act passed into law in Pennsylvania in November 1971. As it relates to the slate belt of eastern Pennsylvania, the act requires, among other things, that a plan be submitted for reclamation of proposed quarry sites. The purpose of the act is to assure improved use of the mined-out land, to prevent pollution, and to eliminate or lessen potential hazards and nuisances. Many of the aesthetic and reclamation problems in the slate belt may be resolved by consideration of the following alternate uses of the dumps and quarries.

The abandoned quarries are large holes (table 1) which cover about 56 acres in the quadrangle and which might be put to a variety of uses, as a few already have been. Three quarries (2, 5, 6) are used as reservoirs by the Bangor Water Company for public water supply.

The Alpha quarry, 2,700 feet east of the post office in Wind Gap, Pa., 2.4 miles southwest of the Stroudsburg quadrangle, was used as a site for oil storage. Oil was piped from Bayway, N.J., stored in the quarry, and later shipped into western Pennsylvania. A floating roof was made up of steel pontoons. Variations in oil level were accomodated by pumping water from and into an abandoned slate quarry 200 feet to the southeast. The project was feasible because of the vertical quarry walls, which allowed the roof to rise and fall readily. The surrounding ground water was monitored with observation wells. The operation began in 1955, but was discontinued about five years later because it was uneconomical to transport the oil. The roof was dismantled in about 1971 (Robert Young, Exxon Co., oral commun., 1973).

Many of the flooded quarries could be used for recreation because they are spring-fed and support a large fish population. Some of the dumps such as those near quarries 1, 16, and 20, have a commanding view of the countryside and might be useful for picnic areas and included in green belts in community planning. The steep slopes of the dumps, however, may not be easily vegetated because of the nearly complete absence of soils. Some dumps might be used as backstops for archery and rifle ranges--a few have already been used for such purposes.

The slate dumps have a variety of potential uses as a resource, as mentioned under "Uses for Slate." Alternatively, the waste slate might be used to fill in the quarry. This operation may be costly, especially in the larger holes, but the rewards of rehabilitation might justify the cost because the area of both the quarries and the dumps could be returned to other uses, such as agriculture, recreation, development, or open space as part of an overall community plan. Of course, proper engineering techniques must be practiced to backfill the hole to assure that there will not be extensive and prolonged settling, as might be expected if the slate waste is end-dumped.

Use of abandoned quarries for sanitary landfills

Three quarries (3, 14, 20) have been used as open public garbage dumps. they were abandoned for such use because of the water-pollution potential. Occasionally, individual quarries have been considered by local planners for potential sanitary landfill sites. A sanitary landfill is one in which the daily accumulation of refuse is compacted and covered with a layer of soil so that the decomposition products are constrained within the site and do not pollute surrounding rock, air, and surface or ground water.

There may be several serious objections to using slate quarries as sanitary landfill sites; (1) drainage into the site, (2) shallow depth to bedrock, (3) high water table, (4) steep slopes, and (5) lack of available impermeable cover material.

(1) Surface runoff water (if allowed to enter the landfill site), as well as rainwater, will percolate through the fill, leach undesirable contaminants, and, if the site is imp operly chosen, pollute ground-water resources if the water table is at or close to the base of the fill or if the fill is in contact with permeable soil or bedrock.

(2) The quarries are in bedrock slate which has abundant openings (cleavage, joints, faults, and bedding-plane partings) that would permit easy flow of leachate into, and pollution of, the ground-water system. It might be possible to close off these avenue of water movement by grouting with an impermeable substance such as clay, but this may require extensive engineering effort and high cost. The disruptive effects on the grout from pressures caused by fluctuating ground-water levels or by chemical reactions between grout and leachate may even preclude use of grouting techniques.

(3) Most slate quarries are flooded; therefore, if they were used as a landfill site, the fill would be below the water table, with the potential for gross pollution of ground water. Isolating the fill from ground water by grouting might be considered, but the problems mentioned above would also apply.

(4) Steep slopes, with the possibility of erosion of the fill by rapid runoff and with the possibility of outflow of leachate onto the surface resulting in stream pollution, cuase a problem that does not generally apply to the quarries in the Stroudsburg quadrangle because the quarries are holes in the ground. However, steep or moderate slopes near a quarry would require drainage diversion to keep runoff from entering the quarry.

(5) Availability of impermeable cover material may not be a problem because of the presence of glacial till overlying the slate at most quarry sites (see the surficial geologic map of the Stroudsburg quadrangle, Epstein, 1969). The use of waste slate as a cover material is to be discouraged because it is highly permeable and would allow rapid percolation of rainwater through the fill.

In summary, some of the physical conditions in abandoned slate quarries present severe limitations to their use as landfills. Extensive engineering practices might be required to eliminate these limitations. In addition, the great depth of some quarries and steep walls would result in difficulty of access into the landfill to cover the daily accumulation of refuse and to compact the covering soil.

It is essential, therefore, that if any abandoned slate quarry is considered as a potential site for a landfill, a detailed study of the geologic and hydrologic conditions be undertaken to evaluate the potential for pollution. The feasibility of overcoming the physical constraints and the engineering costs involved need to be determined for site consideration. Long-term monitoring for possible ground-water contamination may be required. In summary, abandoned slate quarries do not appear to be attractive sites for sanitary landfills.

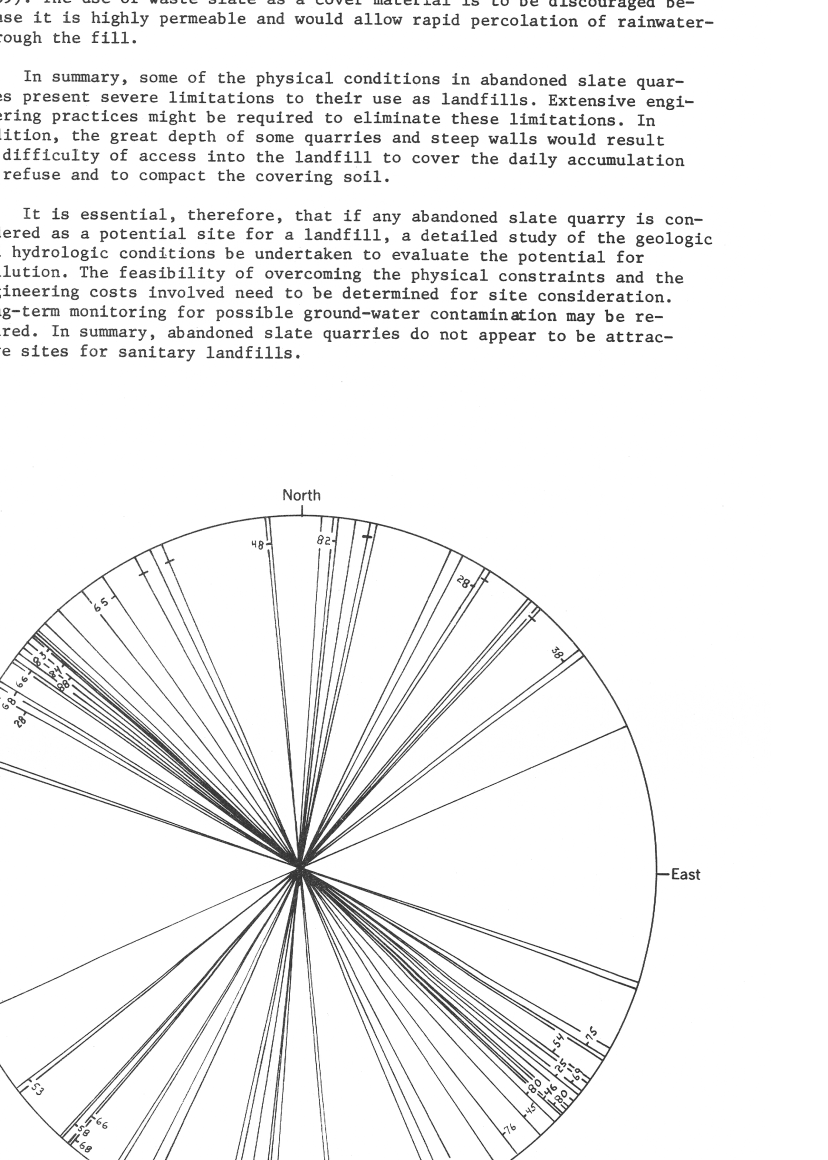

FIGURE 8. Rose diagram showing strike and dip of 40 joints in the Capitol Slate Co. quarry (16). The long lines show the direction of strike; the short ticks and numbers indicate the direction and amount of dip, in degrees, and crossbars indicate vertical joints.

MAP SHOWING SLATE QUARRIES AND DUMPS IN THE STROUDSBURG QUADRANGLE, PENNSYLVANIA - NEW JERSEY, WITH A DISCUSSION OF THEIR ENVIRONMENTAL SIGNIFICANCE

By

Jack B. Epstein

1974

For sale by U.S. Geological Survey, price $1.00 per set